THE RELATION OF WIND DIRECTION TO SUBSEQUENT PRECIPITATION IN CENTRAL OHIO.

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SYNOPSIS.

It is the primary purpose of this paper to show, by means of table and graph, the true existing relation between the observed wind direction and subsequent precipitation. To do this, it is first necessary to establish and consider the probable frequency of precipitation in the district that the apparent relations between the two phenomena may be reduced to the true relations. Hence, the paper is divided into two parts, the first treating the frequency factor, and the second dealing with the relation of the prevailing wind direction to subsequent precipitation, and the application of the frequency factor to determine the true prognostic value of the wind direction.

INTRODUCTION.

PART I. In the rich agricultural regions of central Ohio, rain falls with a frequency probably greater than over many adjacent districts, 3.2 days being the average interval between showers, this interval, of course, varying greatly with the seasons and being considerably less during those periods when rain is most to be expected and slightly greater during the months of minimum frequency.

TABLE 1.—*Frequency of rainy days and of dry and wet spells of variable length, in central Ohio, 1909–1918, inclusive.*

	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	For 10 years.
Number of days considered.	310	282	310	300	310	300	310	310	300	310	300	310	3,652
Number of days with 0.01 inch or more precipitation.	164	117	130	146	134	113	120	113	94	106	94	146	1,477
WET PERIODS.													
Consecutive days with 0.01 inch or more rainfall per day:													
2 days	12	17	15	15	19	10	24	14	17	20	18	22	203
3 days	14	6	10	10	10	5	6	8	8	5	2	9	93
4 days	11	4	4	6	5	5	2	4	2	1	4	2	50
5 days or more	2	1	1	2	0	0	0	1	0	3	1	3	14
DRY PERIODS.													
Consecutive days without measurable rainfall on any day:													
2 days	14	15	16	20	13	19	21	17	10	18	7	16	186
3 days	11	17	11	13	11	14	11	9	5	7	8	7	124
4 days	6	9	8	6	7	9	5	4	5	6	6	11	82
5 days	6	4	2	4	3	3	3	4	7	5	4	6	51
6 days	1	3	2	1	1	3	2	4	6	2	4	2	31
7 days or more	1	2	6	2	7	5	8	10	5	9	9	3	67

Table 1 shows the actual frequency of rainy days and of wet and dry spells in central Ohio, during the period under investigation, 1909–1918, inclusive. From these data may be deduced the rainfall probability [1] and other important facts related to the occurrence of precipitation. However, to determine this frequency in a form applicable to meteorological relations, it is essential that the probable frequency with which rain will occur within 12, 24, or 48 hours after a given instant be computed. To do this, the formula—

Probability of rainfall within—

$$12 \text{ hours} = [R + 12\ (\tfrac{1}{2}\ (A) + B + C + D + E)]/T.$$
$$24 \text{ hours} = [R + 24\ (\tfrac{1}{2}\ (A + B) + C + D + E)]/T.$$
$$36 \text{ hours} = [R + 36\ (\tfrac{1}{2}\ (A + B + C) + D + E)]/T.$$
$$48 \text{ hours} = [R + 48\ (\tfrac{1}{2}\ (A + B + C + D) + E)]/T.$$

[1] For method of determining values of probability, see Hann's Climatology, Eng. ed., p. 61–62; Hellman's "Niederschlage in den Norddeutschen Stromgebieten," vol. 1, p. 179 ffg.

is employed. Here (R) is the time in hours during which rain has fallen; (A), (B), (C), (D), and (E) the numbers of dry periods according to length, 0 to 12 hours, 12 to 24 hours, 24 to 36 hours, 36 to 48 hours and in excess of 48 hours, respectively; and (T) the whole time, in hours, in the period studied. A full discussion of this formula is to be found in an earlier number of the REVIEW.[2]

TABLE 2.—*Showing the probable frequency of precipitation in central Ohio, based upon the rainfall records of Columbus, 1909–1918, inclusive.*

At any instant, probability of rainfall occurring within—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.	P ct.
12 hours	39	29	21	23	20	21	18	13	12	25	31	30
24 hours	56	48	38	41	35	38	35	28	20	31	37	48
36 hours	74	61	51	54	45	50	42	38	32	35	47	59
48 hours	88	68	56	63	56	59	44	47	39	48	57	66

Table 2 sets forth the results of computation from this formula, showing the probability of rain within the given periods subsequent to any instant.

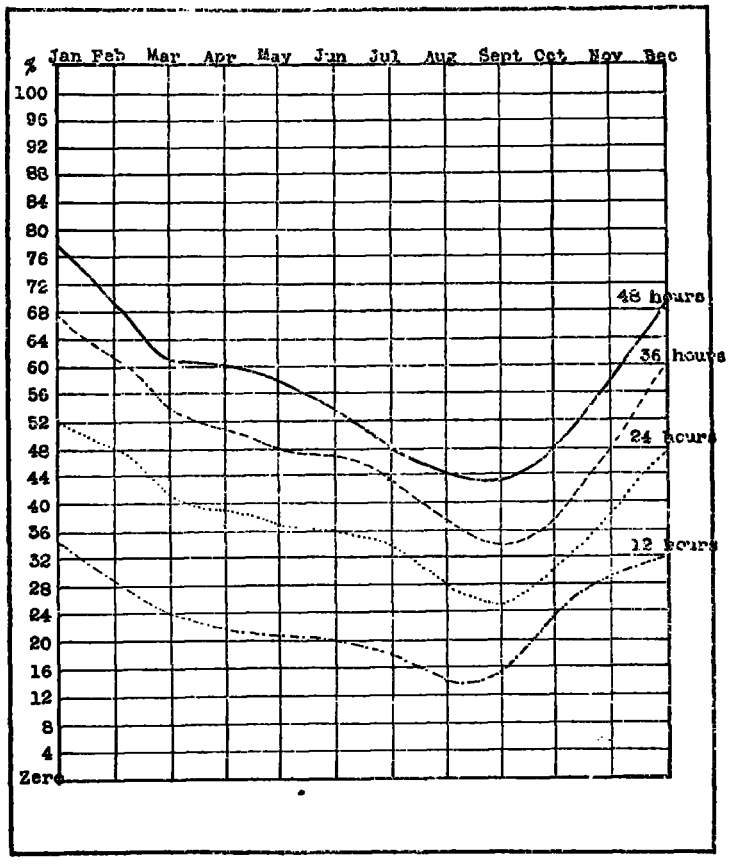

FIG. 1.—Showing the probability of precipitation occurring within 12, 24, 36, and 48 hours after any given instant, based on the records of rainfall at Columbus, Ohio, for the period 1909–1918, inclusive.

Fig. 1 presents graphically the same data. The curves have, however, been smoothed by means of the formula, January = (Dec. + 2 Jan. + Feb.)/4, and show that January is the month of greatest rainfall probability while August and September are the months of least. The

[2] Fog in Central Ohio and its Relation to Subsequent Weather Changes, Howard H. Martin M., W. R., July, 1919, 47: 471–472. See discussion by Dr. C. F. Brooks.

rapid decrease in probability from January to March and the rapid increase in the same value from September to December are especially to be noted. It is further shown that the probability of rain occurring within 24 or 48 hours after a given instant is generally high throughout the year, sufficiently so to render it difficult indeed to establish true prognostic values for many studied phenomena, but unless this factor is given proper consideration, the apparent relations are by no means the true relations.

PART II. That a positive relation exists between certain wind directions and subsequent precipitation is

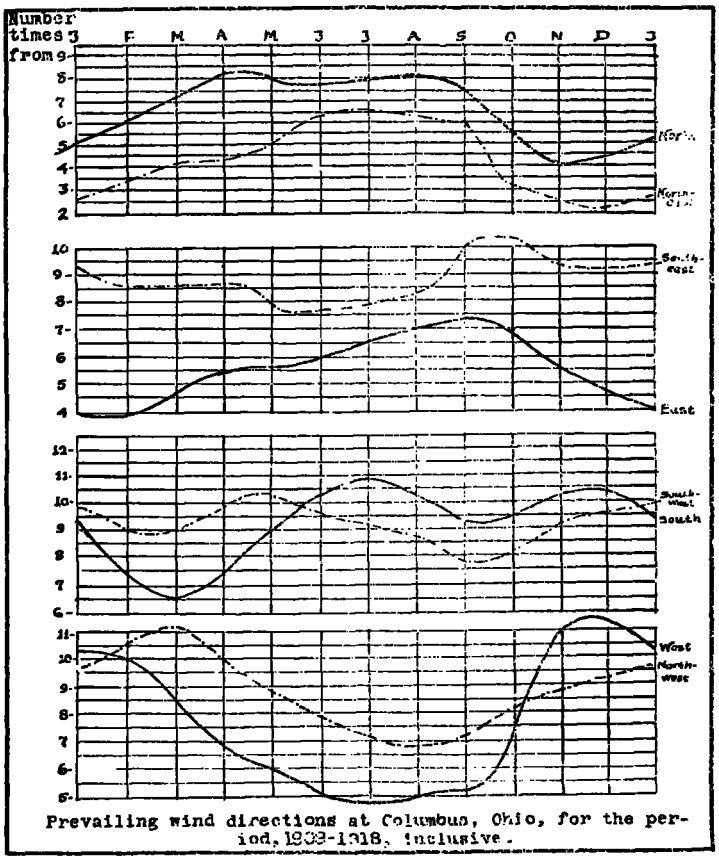

FIG. 2.—Based on twice-daily observations of wind direction, 7 a. m. and 7 p. m.

unquestioned, and a close study of this relation in central Ohio reveals some very interesting points. Each direction has, of course, its month or period of maximum frequency, which fig. 2 brings out very forcibly. For instance, it is to be noted that the north wind prevails more often from April to August than from November to February and that the west wind is more frequent from November to February than during any other part of the year, while the northwest wind attains its maximum frequency in March and its minimum in August. The constancy of the southwest wind is also to be observed, as well as that of the southeast wind, both directions being noted frequently throughout the year.

TABLE 3.—*Showing the number of times the wind was observed from the various directions at Columbus, Ohio, during the period 1909–1918, inclusive. Based on the twice daily observations, 7 a. m. and 7 p. m.*

Number of times wind was observed from—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
North	50	61	66	96	73	79	80	76	91	50	33	45	800
Northeast	22	32	48	35	48	70	64	65	64	47	18	24	537
East	37	35	48	56	55	60	66	68	78	70	52	51	676
Southeast	97	82	85	94	74	75	85	69	107	117	77	96	1,058
South	100	67	63	73	90	102	112	106	87	92	108	105	1,105
Southwest	111	77	93	96	111	93	91	96	69	78	98	92	1,105
West	53	110	87	57	70	47	43	60	37	73	131	115	923
Northwest	97	100	129	90	98	71	75	67	65	90	83	92	1,057
All directions	607	564	619	597	619	597	616	607	598	617	600	620	7,261
Calms	13	0	1	3	1	3	4	13	2	3	0	0	43

Since the curves in fig. 2 were smoothed by means of the simple formula given in Part I, a glance at Table 3 will show the actual number of times the wind was observed from the various directions at Columbus during the period, 1909–1918, inclusive. While the wind prevails from the southwest throughout practically the entire year, the variations shown by the twice daily observations are unique. It is shown that westerly winds prevail from November to March and southerly winds during the remaining months of the year.

TABLE 4.—*Showing the number of times the observed wind direction was followed by precipitation within 12, 24, and 48 hours. Observations at Columbus, Ohio, 1909–1918, inclusive.*

RAIN WITHIN 12 HOURS.

Wind blowing from—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
North	11	11	9	10	4	3	2	7	6	6	1	6	76
Northeast	12	10	3	4	3	3	3	12	3	6	3	3	65
East	6	4	5	4	3	10	4	3	3	4	15	10	71
Southeast	32	35	21	27	45	20	22	6	12	6	5	35	266
South	26	16	10	16	10	15	26	6	20	10	16	26	197
Southwest	36	22	6	34	10	10	22	4	10	21	6	16	197
West	26	17	10	10	16	10	15	8	4	16	12	8	152
Northwest	32	12	6	6	10	6	4	7	4	6	6	15	114

RAIN WITHIN 24 HOURS.

North	25	18	16	26	13	11	7	13	7	12	3	8	159
Northeast	18	13	7	7	10	13	9	18	9	9	7	6	126
East	17	9	20	9	19	31	31	14	13	14	27	44	248
Southeast	57	71	36	59	62	56	44	22	39	26	31	65	568
South	61	42	42	46	60	34	66	42	54	46	38	44	575
Southwest	48	39	16	50	42	36	45	10	36	27	21	46	416
West	42	23	15	16	37	26	20	18	15	34	32	42	320
Northwest	38	28	17	12	26	18	10	9	8	12	12	31	219

RAIN WITHIN 48 HOURS.

North	33	25	24	38	21	20	22	21	18	20	6	9	257
Northeast	20	16	10	10	26	16	21	27	18	15	10	16	205
East	33	30	24	21	30	37	61	35	25	25	33	44	398
Southeast	68	84	40	78	70	72	70	33	60	52	36	85	748
South	86	72	60	70	88	58	76	58	63	57	60	74	822
Southwest	58	60	24	65	50	45	55	18	51	35	33	60	554
West	53	48	24	32	68	50	45	24	18	44	58	78	542
Northwest	58	48	58	38	47	28	22	20	14	28	34	58	453

A careful consideration of Table 4 will reveal the fact that the southeast wind is, in central Ohio, typically a rain wind, with the south wind of slightly less importance.

TABLE 5.—*Showing the apparent prognostic values of wind directions, by months, in terms of percentage of possible, Columbus, Ohio, 1909–1918, inclusive.*

RAIN WITHIN 12 HOURS.

Wind blowing from—	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
	P ct.	*P ct.*	*P ct.*	*P ct.*	*P ct.*	*P ct.*	*P ct.*	*P ct.*	*P ct.*	*P ct.*	*P ct.*	*P ct.*	*P ct.*
North	22	18	14	10	6	4	3	10	7	12	3	14	10
Northeast	54	33	6	11	6	4	5	19	5	13	15	12	15
East	15	10	11	8	5	17	6	4	4	4	25	25	11
Southeast	36	39	24	30	56	25	27	8	12	6	5	38	25
South	26	20	14	23	11	15	24	6	22	11	16	26	18
Southwest	33	27	7	34	9	11	25	4	14	26	6	18	18
West	28	17	11	17	23	20	30	16	8	21	11	7	17
Northwest	32	12	5	7	10	9	5	10	7	6	8	17	11

RAIN WITHIN 24 HOURS.

North	50	30	24	27	18	14	9	18	8	24	10	18	21
Northeast	77	39	14	20	21	19	14	27	14	19	38	25	27
East	42	22	41	16	30	51	47	20	18	20	48	38	37
Southeast	62	78	40	65	77	70	55	27	39	26	33	72	54
South	61	54	60	66	66	34	60	42	60	52	38	44	53
Southwest	44	50	18	50	39	40	50	10	51	34	21	51	38
West	45	23	13	27	53	50	40	36	30	42	29	38	36
Northwest	38	28	13	13	26	26	12	13	13	13	15	35	20

RAIN WITHIN 48 HOURS.

North	66	41	37	40	28	28	27	27	20	40	21	20	33
Northeast	87	47	21	31	54	23	33	42	28	30	55	65	43
East	82	76	51	40	48	62	96	50	34	36	51	88	59
Southeast	76	98	44	87	87	90	87	41	60	52	40	95	70
South	86	96	88	90	98	58	69	58	70	63	60	74	76
Southwest	55	75	27	65	48	50	61	18	72	44	33	66	52
West	60	48	28	53	97	98	92	44	36	55	53	70	64
Northwest	58	48	45	44	47	40	27	28	23	31	42	65	11

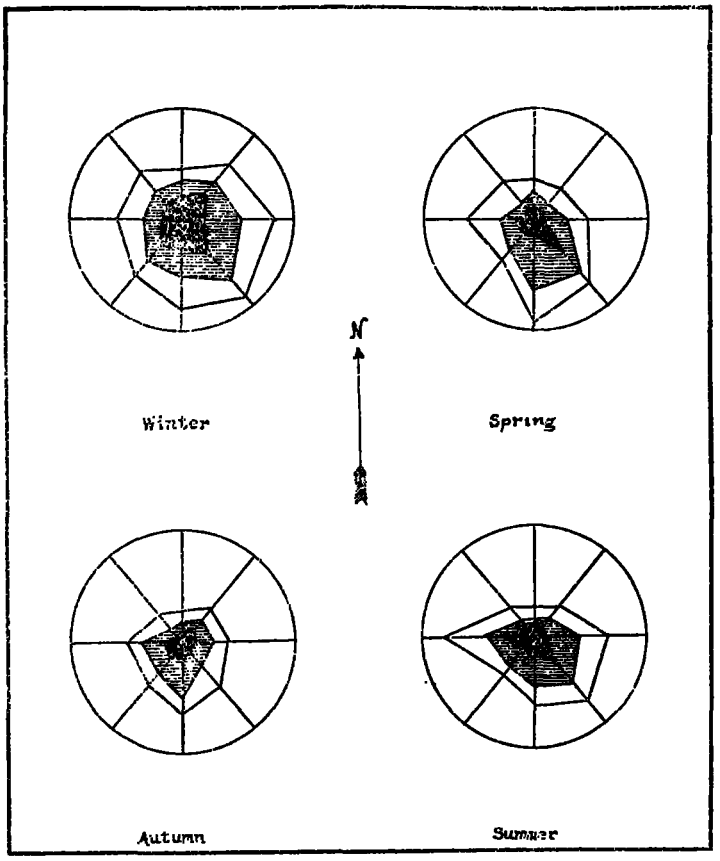

FIG. 3.—Wind roses for Columbus, Ohio, based on 10 years' record, 1909–1918, inclusive, showing the *apparent* relation between wind direction and subsequent precipitation. Solid area indicates 12-hour values; shaded, and open, 48-hour.

Since the actual number of times that precipitation follows an observed wind direction is not, in itself, indicative of the forecast value of that direction, the apparent percentage of prognostic value for each direction has been determined by dividing the total number of times rain has followed a given direction within 12, 24, and 48 hours by the total number of times the wind has been observed from that direction. The results of this computation are shown in Table 5. Wind roses from the same data present the comparative values in a manner more easily comprehended. Figure 3, showing wind-precipitation roses, by seasons, indicates that during the winter months, December to February, inclusive, the rain winds for central Ohio are from the east and southeast to south; that for the spring months, March to May, inclusive, from the southeast and south, with a slight increase in the prognostic value of the west wind; that for the summer, June to August, inclusive, the west wind increases rapidly in prognostic value, and is the rain wind for the season, with east and southeast of secondary importance; and that for autumnal months, September to November, inclusive, the south wind shows the highest value, with the west wind rapidly decreasing in importance as a rainy wind. The west wind is, during the summer months, favorable to the building up of cumuli, which in turn, develop into thunderstorms, hence its importance as a rain-forecast factor during that season. Reference to Table 4 will show that 98 per cent of the observed west winds during the month of June are followed by precipitation within 48 hours, while May and June both show values well above 90 per cent.

The apparent relations of wind direction to the occurrence of subsequent precipitation shown by fig. 3 can not be considered as scientifically accurate, since no

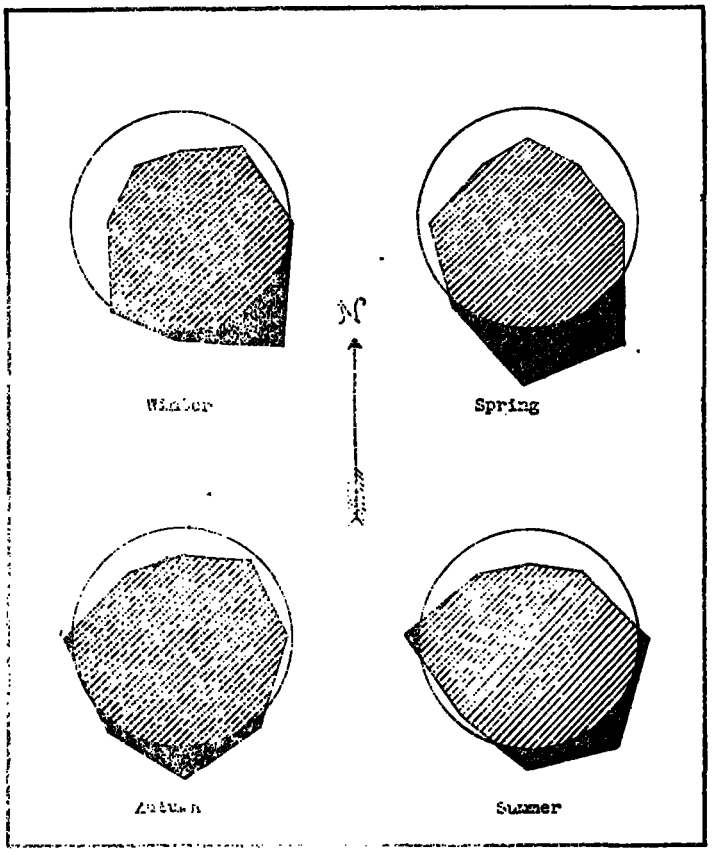

FIG. 4. Showing the relation of wind direction to precipitation within 24 hours, in terms of the true prognostic values. The circle represents the probable occurrence of precipitation within 24 hours, and that portion of the wind rose extending beyond the circle is the true prognostic value for that direction.

consideration has been given the probability of the occurrence of precipitation, regardless of wind direction. These percentages of probability have been computed for central Ohio and by applying the formula

$$\frac{P-p}{100-p}=V$$

where P is the *apparent* percentage of verification, p the percentage possible by chance, as determined in previous tables, and V the true prognostic value, the

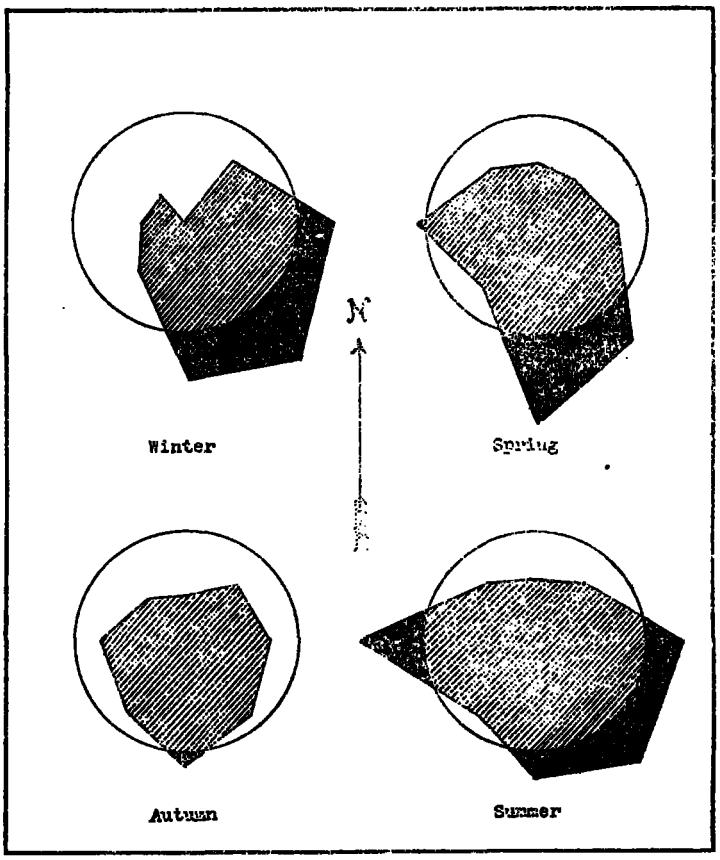

FIG. 5.—Showing the relation of wind direction to precipitation within 48 hours in terms of the true prognostic values. The circle represents the probable occurrence of precipitation within 48 hours, and that portion of the wind rose extending beyond the circle is the true prognostic value for that direction.

apparent relation may be shown reduced to the true prognostic values. This has been done, and is shown graphically in fig. 4, as applicable to the 24-hour relation. In the case of this graph, the circle defines the probability of precipitation possible by chance, the wind-rose showing the true prognostic values of the several directions, only that portion extending beyond the circle, however, representing a positive relation. Thus, it will be readily observed that in the winter, southeast winds are of greatest importance as harbingers of rain, while in the spring, the south wind is of predominating value. The relation between wind and precipitation during the summer and autumn is relatively small, and the west wind appears of increased value.

A glance at fig. 5 will reveal startling differences in the 24- and 48-hour prognostic values. Here, as in fig. 4, the southeast wind appears of greatest prognostic value during the winter months but the east and south winds are also of importance. During the spring, it is to be noted that the south wind continues predominant, and has increased in value appreciably. During the spring also the west wind shows the first positive relation to subsequent rainfall. And during the summer months, it has attained the position of being the rainy wind of the season, showing a high positive value. The winds east to south have also increased in value and may be considered favorable indications of coming showers. In the autumn, there is indicated but a slight relation of the south wind to approaching rain, all other directions being of no importance whatever.

The value of establishing this relation between the several wind directions and approaching weather changes is apparent. Quite frequently indications point to showers, yet with the wind in a dry quarter, the presence of clouds and even of falling barometer can not always be considered faithful prognostics. It may be stated here that the writer has determined further that the south wind, observed at night during the autumn months, was followed 94 per cent of the times observed by precipitation before the following night, but that the observation of this wind in the morning was followed by rain within 24 hours only upon 10 per cent of the times noted. It was also determined that the southeast wind observed at night was the most favorable rain indication during both the winter and spring months, but that the west wind at night during the summer was followed by rain within 24 hours 88 per cent of the times observed and within 48 hours 97 per cent of such times. Further, it is believed that the relation of the wind at sunset or shortly thereafter is, in central Ohio at least, of greatest value to subsequent rainfall, and that in the morning is of secondary importance. In other words, the presence of a wind from a direction shown in figs. 4 or 5 to be a rain-wind will, if observed at sunset, be followed by precipitation with a far greater degree of certainty than the same wind direction observed in the morning. Many times the southeast wind at night precedes a cloudy morning, with the wind in the south or southwest, and with precipitation following within a few hours, but rarely does the southeast wind of the morning precede rain by less than 24 hours.

The writer believes that the direction of the surface wind, if studied carefully, will reveal many peculiarities in itself, which, in turn, will be of the greatest value to local forecasting. As before stated, there can exist no doubt but that a positive relation exists between certain surface wind directions and subsequent rainfall, and with the data at hand, study can but prove of incalculable value in the determination of this relation.